# APPENDIX 32

# Technical Memorandum

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| Date: | June 30, 2010 |
| To: | Virginia Association of Municipal Wastewater Agencies |
| From: | Clifton F. Bell, Malcolm Pirnie, Inc.<br>Will Hunley, Hampton Roads Sanitation District |
| Re: | Review of USEPA James River Chlorophyll-a Recommendations and Supporting Materials |

The following technical comments are related to materials contained in the USEPA Chesapeake Bay Program's (CBP) presentation entitled "Achieving Attainment of the James Chlorophyll Water Quality Standard", dated June 18, 2010. In this presentation, EPA concludes that nutrient loadings of 23.5 TN/2.34 TP were estimated to achieve the James River chlorophyll-a standards. If these specified loadings were chosen as basin allocations they would result in a reduction of 4.6 TN/1.31 TP relative to the presently established tributary strategy loads of 28.1 TN/3.65 TP. However, the available technical information does not adequately support or justify nutrient reductions beyond the existing tributary strategy level for the following reasons:

- The James River chlorophyll-a modeling framework continues to have major technical problems including poor calibration and unexplained anomalies.
- The CBP has only partially recognized/addressed modeling problems, and has lacked clear criteria for evaluating the model accuracy, precision, and utility. The result has been a semi-arbitrary selection of which model results/data to use for load allocation or which model results to ignore.
- The predicted changes in chlorophyll-a (on the order of 1-2 ug/l seasonal average and 2-4% in terms of non-attainment rates) are smaller than those than can be precisely distinguished by the model, detected in monitoring data, or concluded to have ecological significance.
- Relatedly, the predicted response of chlorophyll-a to nutrient load reductions are extremely "flat" in key segment-seasons. Such a misapplication of the modeling framework could lead to huge expenditures without significant changes in standards attainment or result in tangible environmental improvement.

Specific comments are provided below:

1. *The James River chlorophyll-a modeling framework has major calibration/behavior problems that have only been partially recognized and addressed*: Since December 2009, VAMWA has raised questions on the James River chlorophyll-a modeling calibration and utility (Bell, elec. comm., 4 Jan. 2010). Although the CBP has not specifically responded to the VAMWA's request for a detailed examination of model calibration

problem, a review of the June 18, 2010 materials indicates that the CBP has recognized certain model calibration and post-processing issues, including the following:

- Obviously erroneous calibration in certain segment-seasons (JMSTFL, JMSPH).
- Model post-processing problems as evidenced by problematic regressions used to scenario-transform the data.
- Unexplained model anomalies
- High leverage of few data in the data transformation process (e.g., September 1999 data at LE5.2).

Although these issues have been recognized for certain segment-seasons in which there were most obvious, we see no indication that the CBP has performed a more systematic review of the same issues in all segment-seasons, determined the causes/extent of model anomalies, or fully evaluated the predictive capabilities of the model. The main criteria that CBP appears to have used to deem model results as acceptable for a given segment-season appear to be:

- Whether or not the model predicts the approximate range of chlorophyll-*a*, without a systematic examination of whether the model correctly predicts the magnitude and direction of interannual *changes* in chlorophyll-*a*.
- Whether or not the model predicts decreasing chlorophyll-*a* with decreasing nutrient loads, without an examination of whether the same problems that cause counterintuitive results in some segment-seasons might also be more causing more systematic, less obvious problems in other segment-seasons.

Under the current approach, management decisions are highly susceptible to the criticism that CBP has been highly selective and partially arbitrary regarding which model predictions are usable and which are not. It would be recommended that the CBP develop a set of objective criteria for evaluating model behavior that includes: (1) a systematic evaluation of the ability of the model to quantify changes in chlorophyll-*a*; and (2) an evaluation of the causes of problem model chlorophyll-*a* predictions, and how those causes might affect the model accuracy/precision on a model global level.

2. *The predicted changes in chlorophyll-*a *are smaller than can be precisely quantified by the model*. Based on a review of the June 18, 2010 materials, CBP's justification for going beyond the 190/13 allocation level appears to be very small decreases in chlorophyll-*a* and non-attainment rates:

- 2-3% reductions in non-attainment in selected segment seasons (JMSTFL, JMSMH)
- 1-2 ug/L reduction in chlorophyll-*a* in selected segment seasons. (see Attachment A)

It is a misapplication of the model framework to claim that it is capable of distinguishing between model scenarios at these levels, or that major management decisions should be

made based on these tiny predicted shifts. The precision of chlorophyll-*a* predictions can be expected to be significantly less than that for mainstem Bay dissolved oxygen (D.O.), which enjoys a much better calibration. If the model cannot distinguish between D.O. non-attainment rates of 0% and 1% (as acknowledged by CBP), the spread in distinguishable non-attainment rates for chlorophyll-*a* can be expected to be greater. Given the strong implicit margin of safety of the Bay TMDL, it cannot be concluded that model is precise enough to distinguish between scenarios that predict 0-1% nonattainment and 2-4% nonattainment.

The post-processing regression equations for the key scenarios in question might not even be significantly different. Examining the chart on the lower right of slide 12, is appears that the offset in regression equations for multiple scenarios is significantly less than the spread of data around the regression lines. (It is recommended to zoom in on the slide to visually examine the three scenario lines between the calibration and E3 scenarios). Although VAMWA did not have access to the regression data, is appears likely that statistical hypothesis testing would indicate that the parameters of these regressions are within each other's 95% confidence limits, and they are probably not even statistically distinguishable.

3. *The predicted changes in chlorophyll-*a *are smaller than could be detected in monitoring data.* It can demonstrated that tiny predicted shifts in chlorophyll-a between the 190 scenario and the "between 170/Potomac" scenario would not even be detectable in light of environmental, sampling, and analytical variability. For example:

(a) Power analysis demonstrates that even after long (25 year) monitoring periods, the minimum significant difference (MSD) in seasonal mean chlorophyll-a would be in the 2-4 ug/L range for most attaining segment seasons (Attachment B). Thus, it appears that the modeled shift in chlorophyll-*a* between the 190 and the "between 170/Potomac" scenario would probably not be detectable in the monitoring data.

(b) Based on a review of laboratory split sample results for the 1991-2000 James River data obtained from the CBMP data hub, the median relative percent difference (RPD) in chlorophyll-*a* samples was about 16 percent, corresponding to 1-4 ug/L chlorophyll-*a*, depending on segment and season (Attachment C). Thus, analytical variability alone is equal to or greater than the modeled shifts in chlorophyll-*a* between the 190 scenario and the "between 170/Potomac" scenario. Consideration of field (sampling) variability would the total variance of chlorophyll-*a* measurements to increase even further.

4. *The predicted changes in chlorophyll-*a *are not ecologically significant.* The difference in chlorophyll-*a* levels predicted between tributary strategy and the proposed reduced allocation scenarios (on the order of 1-2 ug/l seasonal average and 2-4% in terms of non-attainment rates) are exceptionally small in magnitude. This estimated level of change is too small to be seriously considered a matter of practical importance or consequence to Bay restoration. Even if the model could adequately discern such differences (which we dispute as discussed above) they would probably not result in tangible environmental

benefits. It should be remembered that the chlorophyll-*a* standard development process was acknowledged by VDEQ and stakeholders to be highly imprecise. Although its precision could not be quantified, revisions made to the criteria values on the basis of attainability were well within the differences described above. This shows that environmental conditions are essentially equivalent at the scale of a few micrograms.

VAMWA has consistently recommended that the James River chlorophyll-*a* standards eventually undergo reevaluation to take advantage of more recent monitoring data and research. It would be inappropriate to slash load allocations unless such a process clear demonstrated the ecological need.

5. *The predicted response of chlorophyll-a to nutrient load reductions are extremely "flat" in key segment-seasons.* This means that very large reductions in nutrient loading would result in only very small incremental reductions in chlorophyll-*a* concentrations and/or reductions in non-attainment rate. For example the critical segments of the tidal freshwater and lower estuary are predicted to have response rates of approximately 0.4 and 0.2 ug/l chlorophyll response per Mlb/yr TN reduction. Such a misapplication of the modeling framework could lead to huge expenditures without significant changes in standards attainment or result in tangible environmental improvement.

In previous Bay TMDL comments HRSD estimated nutrient control capital costs at $150M per mpy TN reduction. Clearly, such a misapplication of the modeling framework could lead to huge expenditures without significant changes in standards attainment or result in tangible environmental improvement.

## CONCLUSIONS

Although we recognize the tight schedule for the Baywide TMDL, we do not believe it is the best interests of Virginia or the environment to make large cuts to allocations on the basis of near non-detectable shifts in chlorophyll-*a* predicted by a problematic, imprecise model. It is recommended that TMDL allocations for the James River be based on the 191/14.4 (Tributary Strategy) scenario, and that Virginia initiate a longer-term process for reevaluating and refining the modeling framework, chlorophyll-*a* standards, and load allocations as necessary.

## ATTACHMENT A
### Estimation of the Magnitude of Model-Predicted Changes in Chlorophyll-*a*

This attachment describes how the CBP presentation entitled "Achieving Attainment of the James Chlorophyll Water Quality Standard" (dated June 18, 2010) was used to interpret the magnitude of predicted changes in seasonal average chlorophyll-*a* between the 190/12.7 scenario and the "between 170/Potomac" scenario. VAMWA did not have access direct access to model output or post-processing regression equations for most segments and months. Therefore, the approximate magnitude of the shift was estimated by examination of regression relationships for key segment-months:

- JMSTFL April 1995 (slide 6), taken as representative of JMSTF Spring
- JMSMH September 1999 (slide 12), taken as representative of JMSTF Summer

The offsets in predicted ln_chla between regression lines for different scenarios were quantified as a function of decreases in the James River total nitrogen load. These demonstrated an approximately linear relation between ln_chla and TN load, with the following approximate slopes:

- JMSTFL Spring: 5.72E-2 reduction in ln_chla for every 1 Mlb/yr TN reduction in the James River TN load.
- JMSMH Summer: 3.37E-2 reduction in ln_chla for every 1 Mlb/yr TN reduction in the James River TN load

The "between 170/Potomac" scenario represents a 3.1 Mlb/yr reduction in James River TN load, relative to the 190 scenario. This corresponds to the following predicted reductions in ln_chla:

- JMSTFL Spring: 0.177 reduction in ln_chla.
- JMSMH Summer: 0.104 reduction in ln_chla

As these JMSTF-Spring and JMSMH-Summer approach attainment with the existing chlorophyll-*a* criteria, their seasonal average chlorophyll-a values will approach 15 ug/L and 10 ug/L, respectively. At these levels, the predicted reduction in ln-chla listed above would correspond to the following reductions in chlorophyll-a concentration:

- JMSTFL Spring: ~2 ug/L reduction in chlorophyll-*a*
- JMSMH Summer: ~1 ug/L reduction in chlorophyll-*a*

## ATTACHMENT B
## Power Analysis of Seasonal Mean Chlorophyll-*a*

A two-sample power analysis was conducted to determine the minimum significant difference (MSD) in the seasonal mean chlorophyll-*a* concentrations that could be expected in the James River, Virginia. Values of $\alpha$ and $\beta$ were set to conventional values of 0.05 and 0.2, respectively. The value of n was selected as 25, representing the approximate number of years for which a pre-TMDL seasonal mean could be calculated for most James River segments, and also representing a 25-year post-TMDL monitoring period.

In order to determine the standard deviation of the chlorophyll-a seasonal means, 1991-2000 monitoring data were obtained from the CBMP data hub. Seasonal means were calculated simple as the mean of all surface layer chlorophyll-*a* values by segment and season (spring & summer). These seasonal mean values were compared to water quality criteria. Standard deviations were calculated for segment-seasons for which the seasonal mean values were below the criteria (Table A.1). This represents a simplification of the full CFD-based assessment process, but was conducted to identify the approximate standard deviations of seasonal mean chlorophyll-a values in segment-seasons that are likely to be in attainment.

#### TABLE A.1—Standard Deviation of Seasonal Mean Chlorophyll-*a*, 1991-2000

| Season | JMSMH | JMSOH | JMSPH | JMSTF1 | JMSTF2 |
|--------|-------|-------|-------|--------|--------|
| Spring | 2.8 | 4.5 | 2.4 | 4.1 | 2.1 |
| Summer | 2.3 | 3.7 | 1.9 | 4.2 | 3.9 |

The power analysis was conducted using the software of Lenth (2010). Result (Table A.2) indicate that the MSD in seasonal mean chlorophyll-*a* is 2-4 ug/L for most attainment segment-seasons.

#### TABLE A.2—Minimum Significant Difference in Seasonal Mean Chlorophyll-*a*

| Season | JMSMH | JMSOH | JMSPH | JMSTF1 | JMSTF2 |
|--------|-------|-------|-------|--------|--------|
| Spring | 2.3 | 3.7 | 1.9 | 3.3 | 1.7 |
| Summer | 1.9 | 3.0 | 1.5 | 3.4 | 3.2 |

## ATTACHMENT C
### Relative Percent Difference of Chlorophyll-*a* Measurements

The relative percent difference (RPD) of chlorophyll-*a* lab splits were calculated from 1991-200 James River data obtained from the CBMP data hub. An RPD was calculated for each sampling event for which chlorophyll-*a* data were reported for both "S1/LS1" and "S1/LS2" sample types. RPD was calculated using the following equation:

$$RPD = \left| \frac{x_1 - x_2}{(x_1 + x_2)/2} \right| \times 100$$

A total of 595 data pairs were available for the calculation. The mean RPD was 35%, but this value was strongly affected by outliers. The median RPD was 16%. There was no obvious graphical trend in RPD with chlorophyll-*a* magnitude.

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